

Application of Different Tracers to Evaluate the Flow Regime at Riverbank Filtration Sites in Berlin (Germany)

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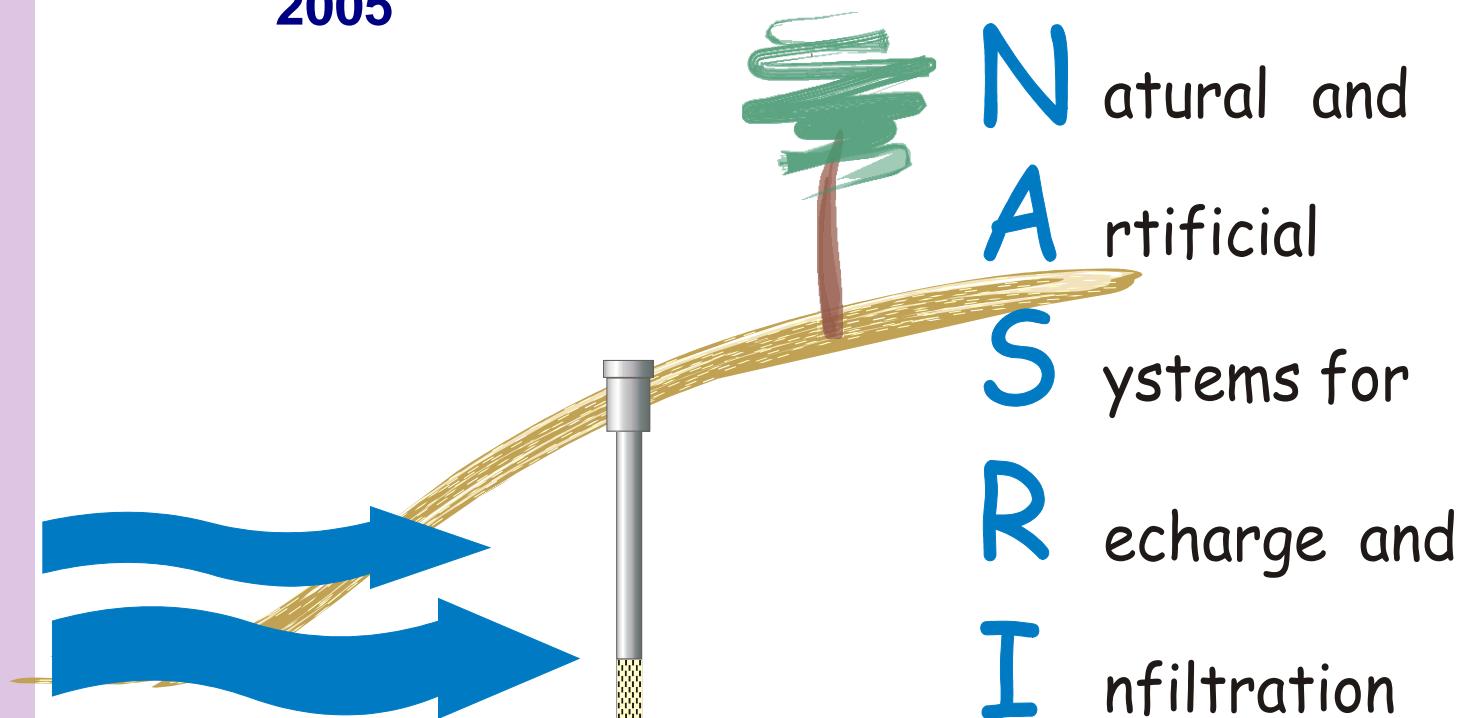
Talk outline

Introduction

- Introduction
 - Nasri
 - Berlin situation
- Methods/Tracer
- Results
 - Surface water
 - Bank filtrate
 - *Microcystin Experiments (Gesche Grützmacher, UBA Berlin)*
- Summary/Conclusions

Research program in Berlin to study the fate of pathogens and organics, geochemical processes and hydraulics in bankfiltration and artificial recharge systems at laboratory, semi-technical and field scale.

May 2002 – May
2005



Algae: Retention and elimination of cyanobacterial toxins (microcystins) (Dr. Chorus/Dr. Bartel, German Environmental Agency).

Bacteria: Using bacteriophages, indicator bacteria and viral pathogens for assessing the health risk (Dr. Lopez-Pila, Dr. Szewzyk, German Environmental Agency).

Drugs: Occurrence and fate of drug residues and related polar contaminants (Dr. Heberer, Technical University, Dr. Dünnbier, Berlin Water Company).

Hydrogeo: Hydrogeological-hydrogeochemical processes using a multi tracer approach (Prof. Pekdeger, Free University)

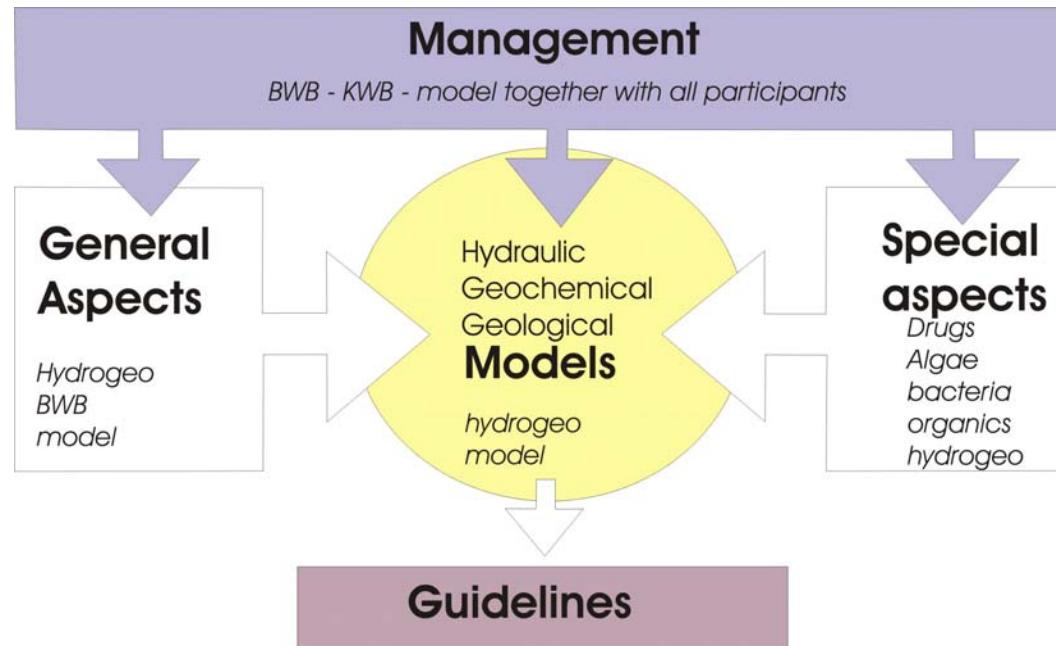
Models: Integrated modelling concepts: coupled groundwater transport and biochemical reactions (Prof. Nuetzmann, Institute for Freshwater Ecology)

Organics: Organic substances— process studies (Prof. Jekel, Technical University)

BWB: Data management, water sampling, analyses

Objectives of Nasri

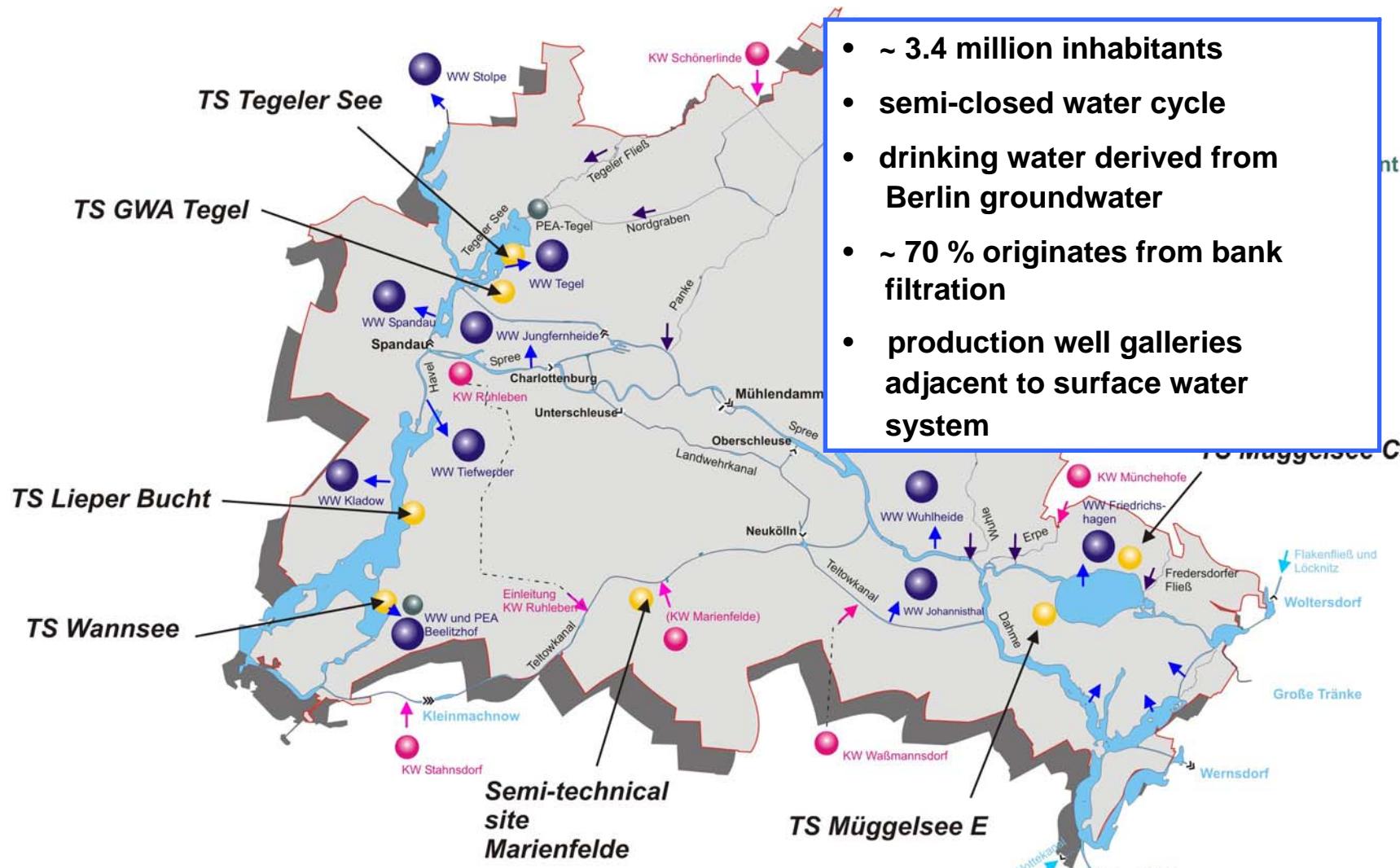
Introduction



- To ensure the long term sustainability of the groundwater resource and drinking water quality through the bankfiltration and the groundwater recharge process
- To expand the Know-How and quantify the relevant processes
- To obtain quantitative and qualitative guidelines for proper design and optimised operation of existing sites and for transfer of the integrated knowledge to other locations (use of models etc..)

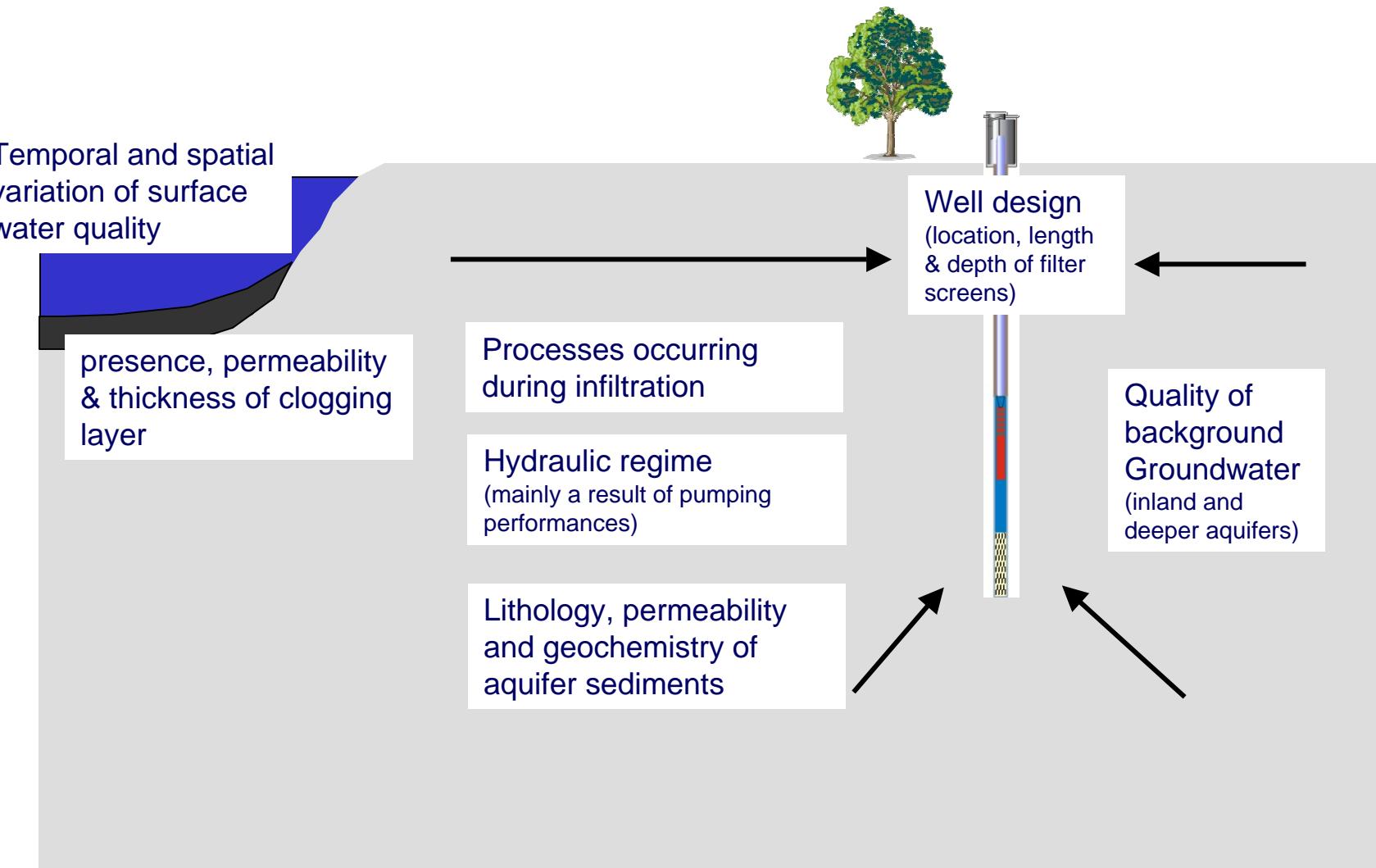
Berlin characteristics

Introduction



Factors influencing the raw water quality

Introduction



Objectives

Objectives

to use a variety of tracers at several field-sites in order to:

- estimate the proportion of treated wastewater in the surface water system
- estimate the proportion of bank-filtrate (and likewise deeper and landside groundwater) in the production wells
- derive travel times from the surface water to the production wells
- understand flow regime

T/He age dating

Methods



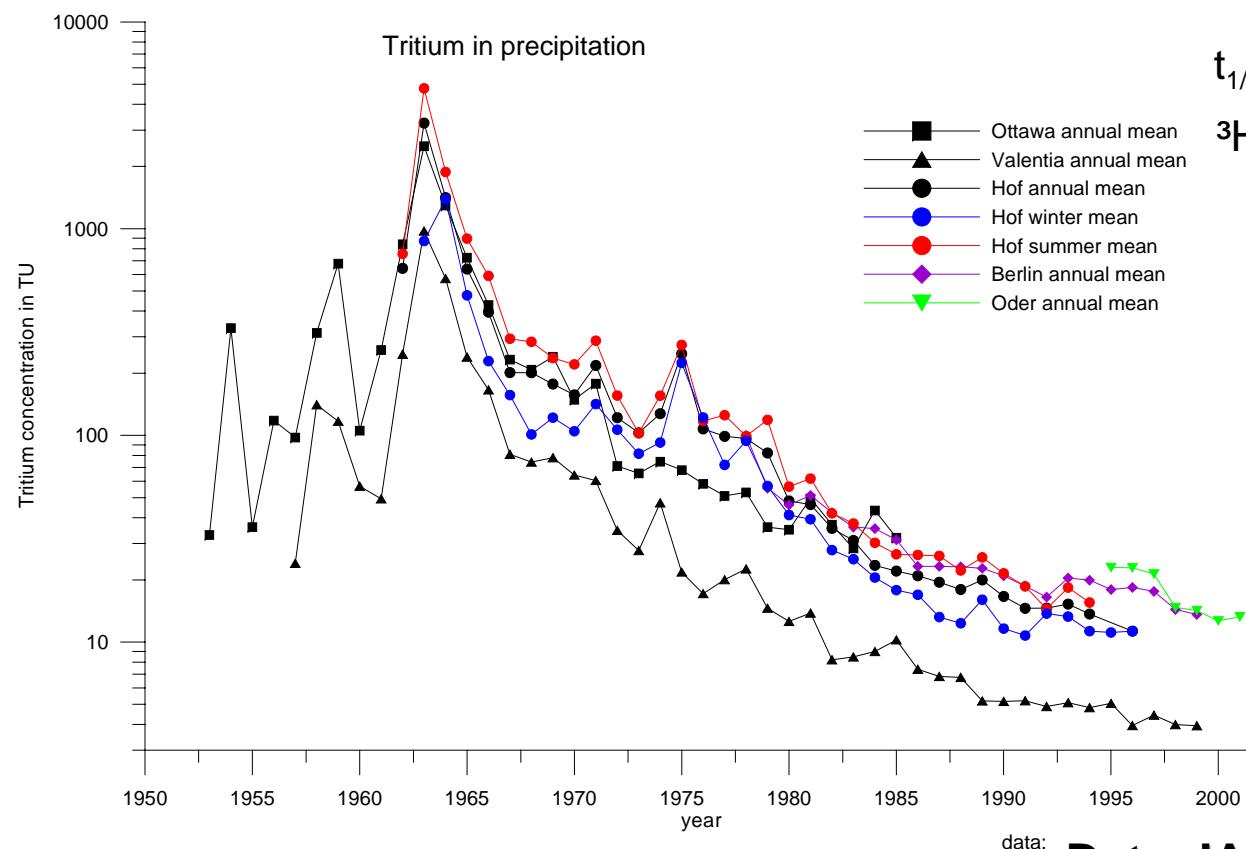
in water: 1TU 1T / 10^{18} H 0.118Bq/kg

Groundwater „age“:

$$\tau = t_{1/2} / \ln 2 \cdot \ln (1 + {}^3\text{He}^*/\text{T})$$

$$t_{1/2} = 12.32\text{y}$$

${}^3\text{He}^*$ = tritiogenic He



Data: IAEA, BfG

Overview on applicable tracers in Berlin

Methods

Tracer:	Origin:	Useful for the interpretation of:	Difficulties:
δD , $\delta^{18}O$	surface water with seasonal variations	water movement	none, conservative tracer
Temperature	surface water with seasonal variations	water movement	retarding
Cl^-	surface water with seasonal variations	water movement	only if influence of saline groundwater can be excluded
Cl^- , Na^+ , B	saline deeper groundwater	proportion of deeper saline groundwater	may vary strongly locally
SO_4^{2-}	dissolution of gypsum derived from building rubble in the shallow aquifer	proportion of shallow “native” groundwater	may vary strongly locally
B	surface water, effluent	water movement, proportion of bank filtrate in raw water	only if influence of saline groundwater can be excluded
Gd	surface water, effluent	water movement, proportion of bank filtrate in raw water	possibly degradable
EDTA	surface water, effluent	water movement, proportion of bank filtrate in raw water	sometimes the background groundwater has also got very high concentrations
Sr	surface water, very few seasonal variations	proportion of bank filtrate in raw water	not always applicable
T/He	Surface water, through atmospheric input	groundwater “age”	minimum age required is 2 months

Mixing calculation

Methods

$$X = [C_w - C_{GW}] / (C_{SW} - C_{GW}) * 100 [\%]$$

X = Percentage of bank-filtrate in the production well

C_w = Tracer concentration in the production well

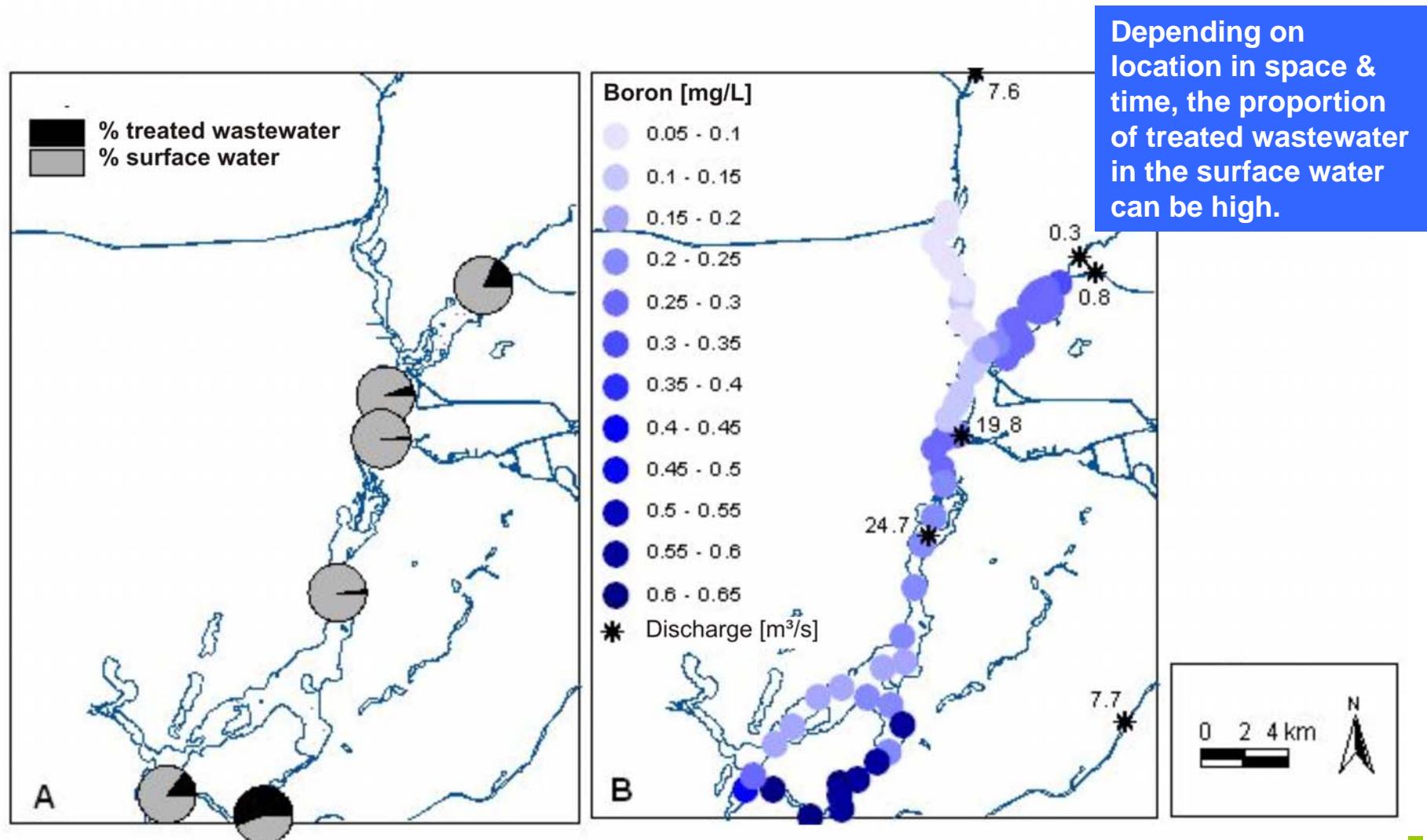
C_{SW} = Tracer concentration in the surface water

C_{gw} = Tracer concentration in the groundwater

Surface water

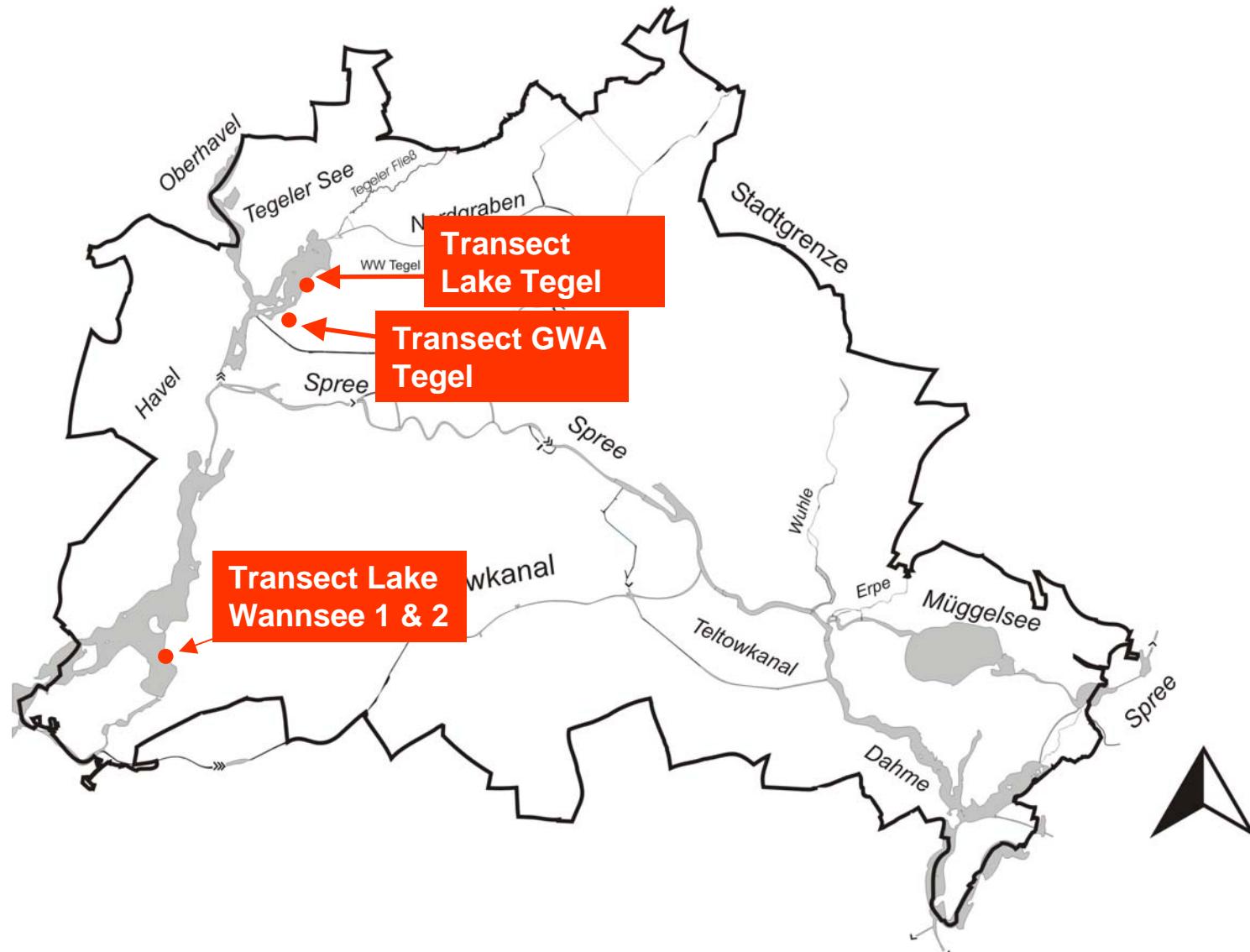
Results

Spatial variations of B and percentage of treated wastewater in the surface water



Location of field sites

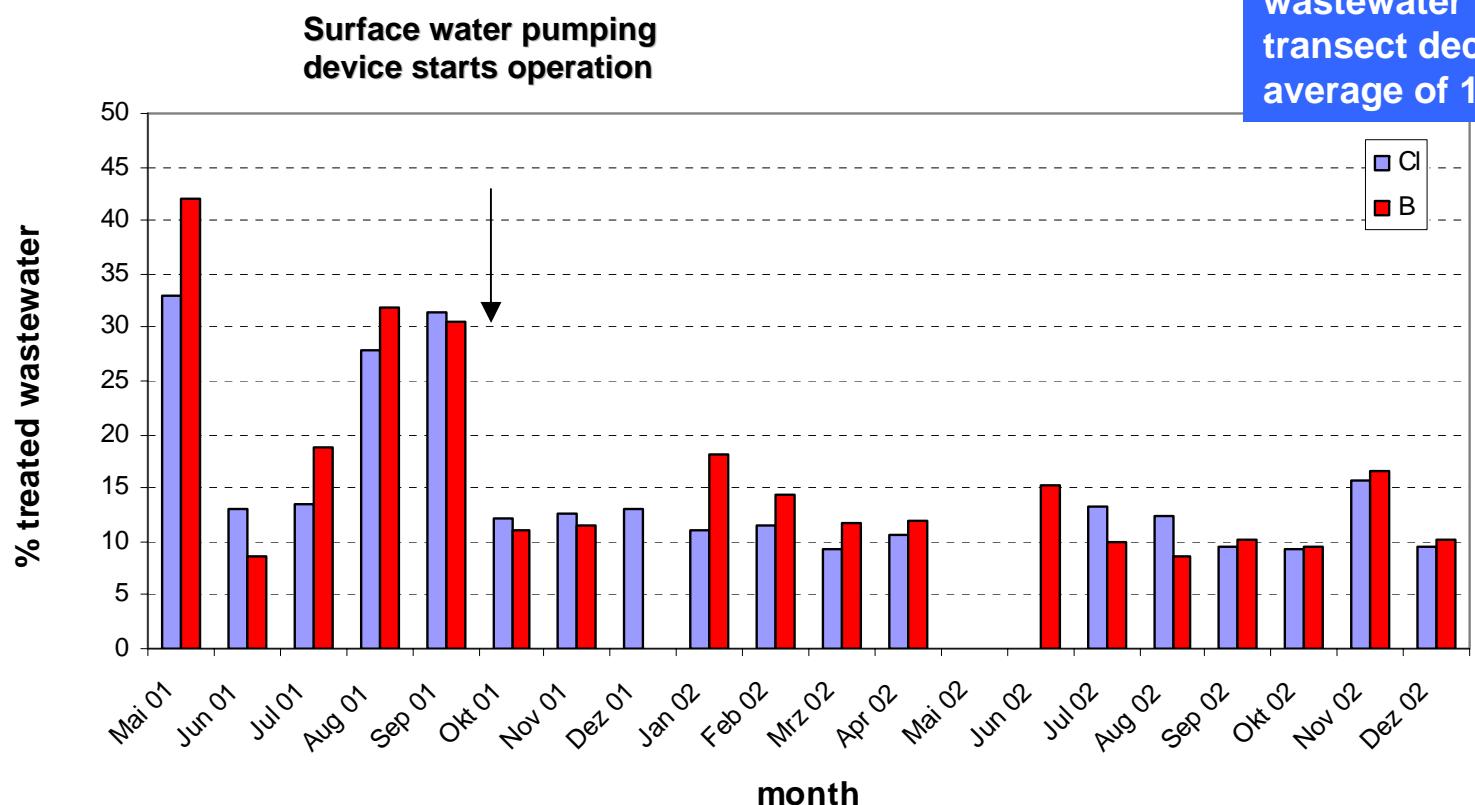
Results



Surface water

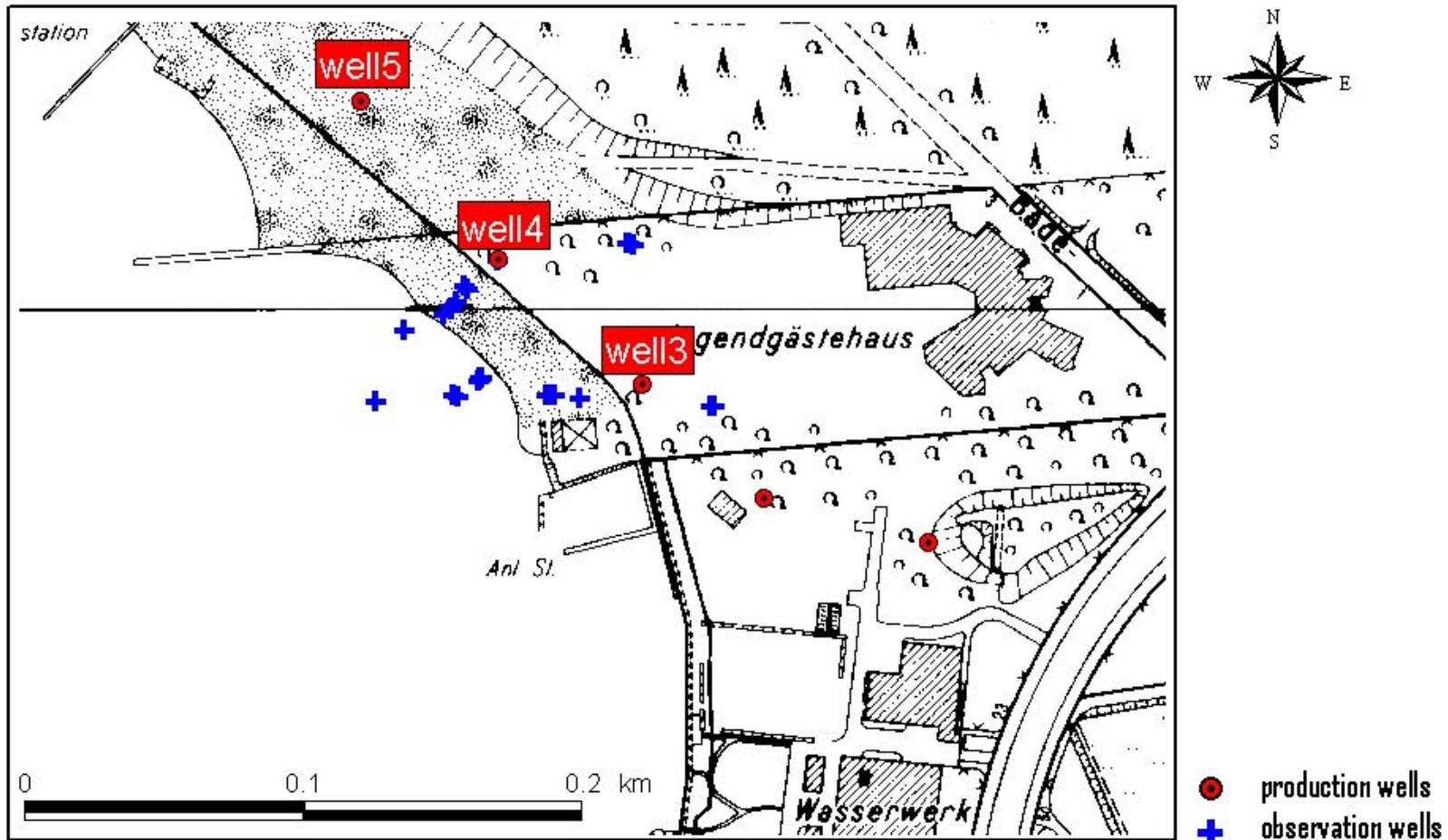
Results

Percentage of treated wastewater in Lake Tegel near the transect



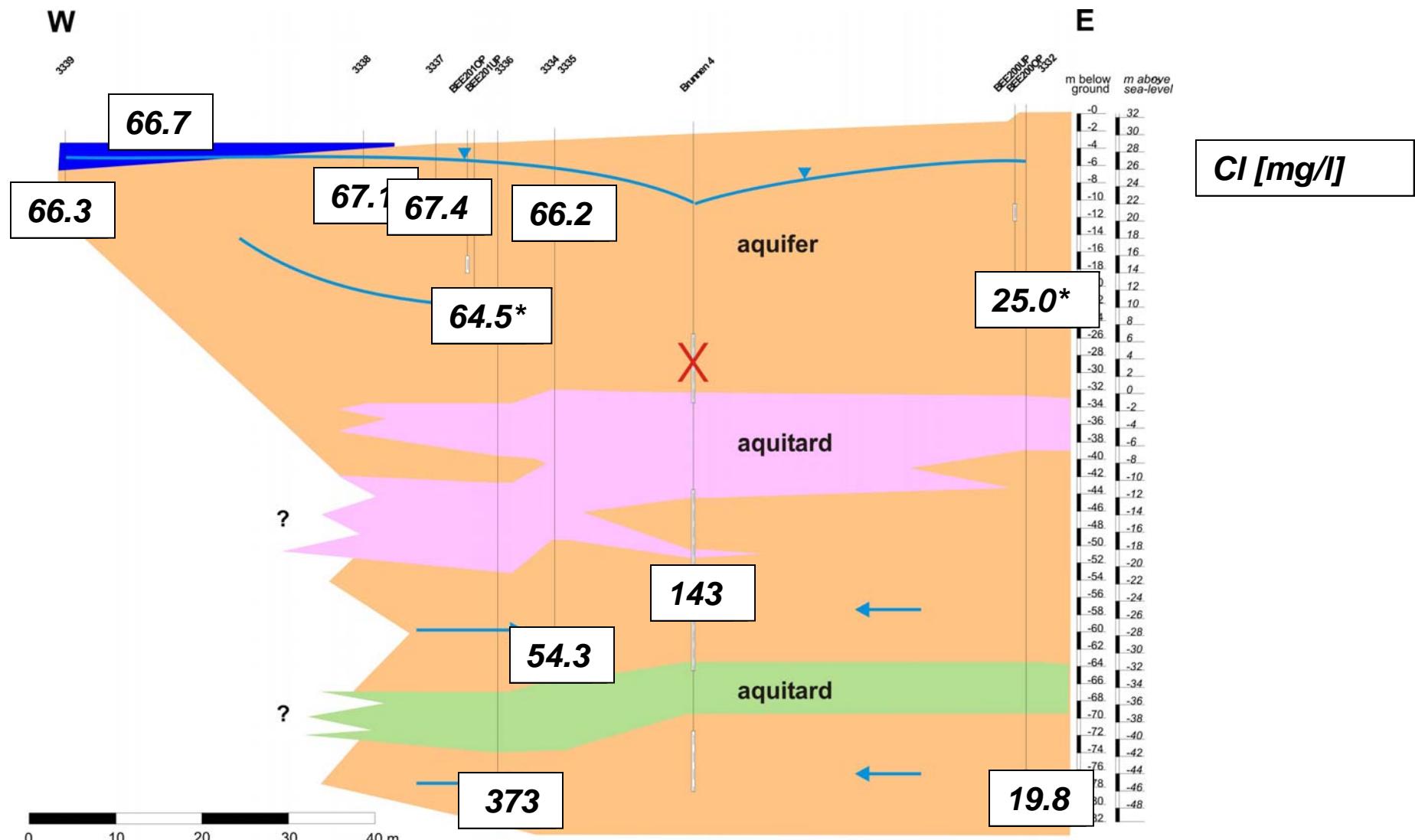
Field-site Lake Wannsee

Results



Transect Lake Wannsee 1, hydrochemistry

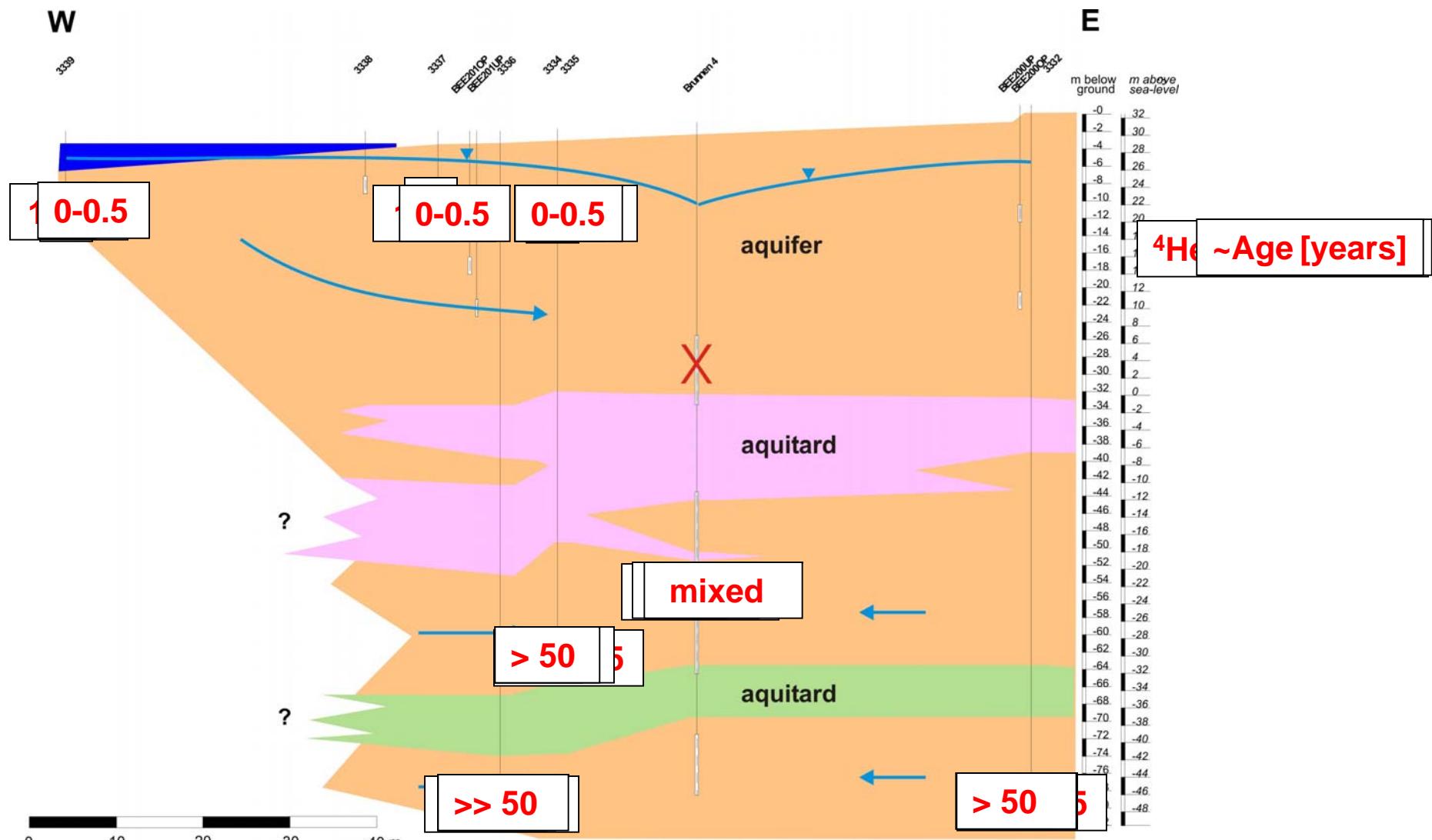
Results



Data: llat average 10/2000 – 11/2001
 *BWB 01/2003 – 04/2003

Transect Lake Wannsee 1, age dating

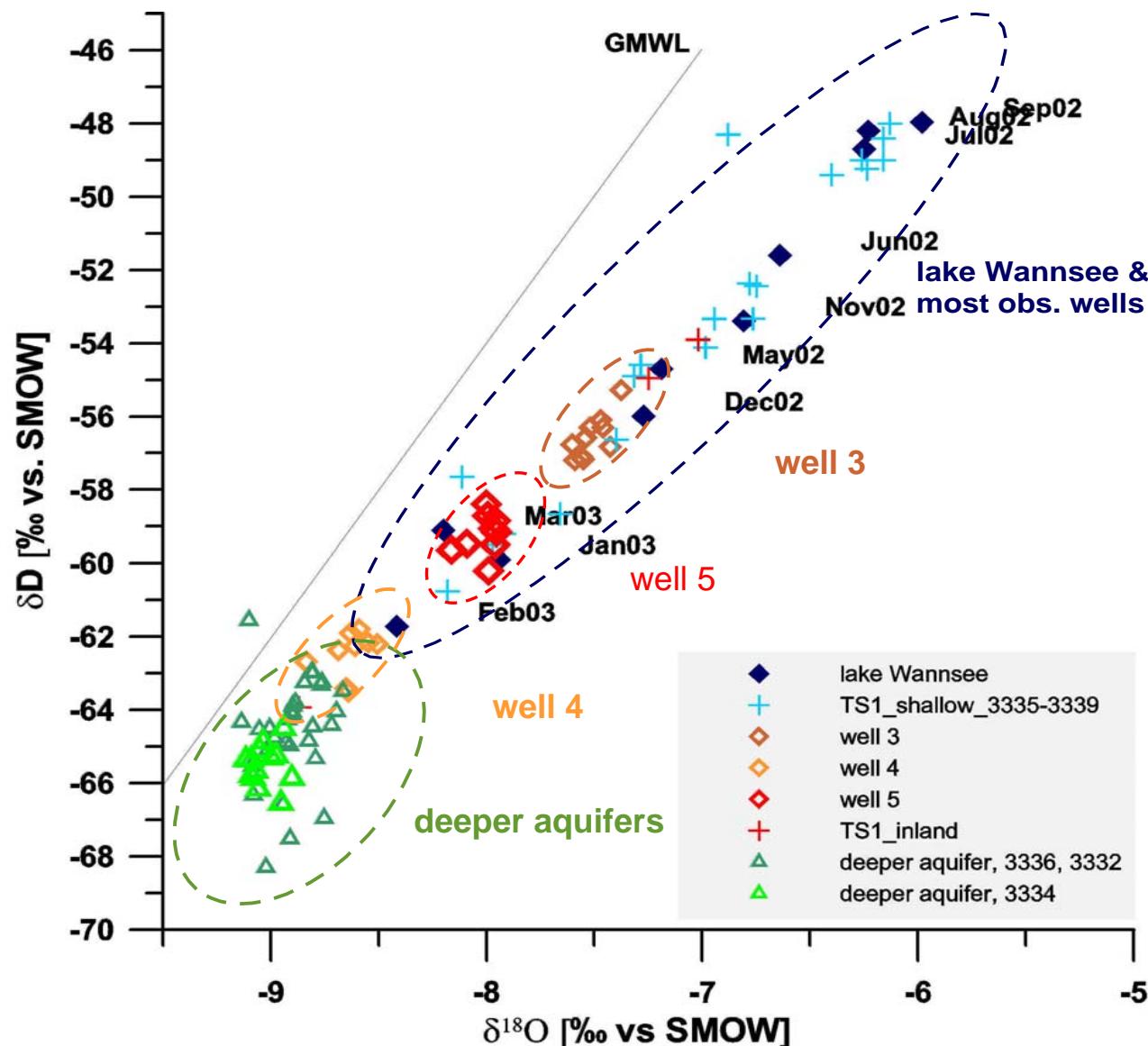
Results



Data: Helis Laboratory, University of Bremen

Transect Lake Wannsee 1, dD versus d¹⁸O

Results



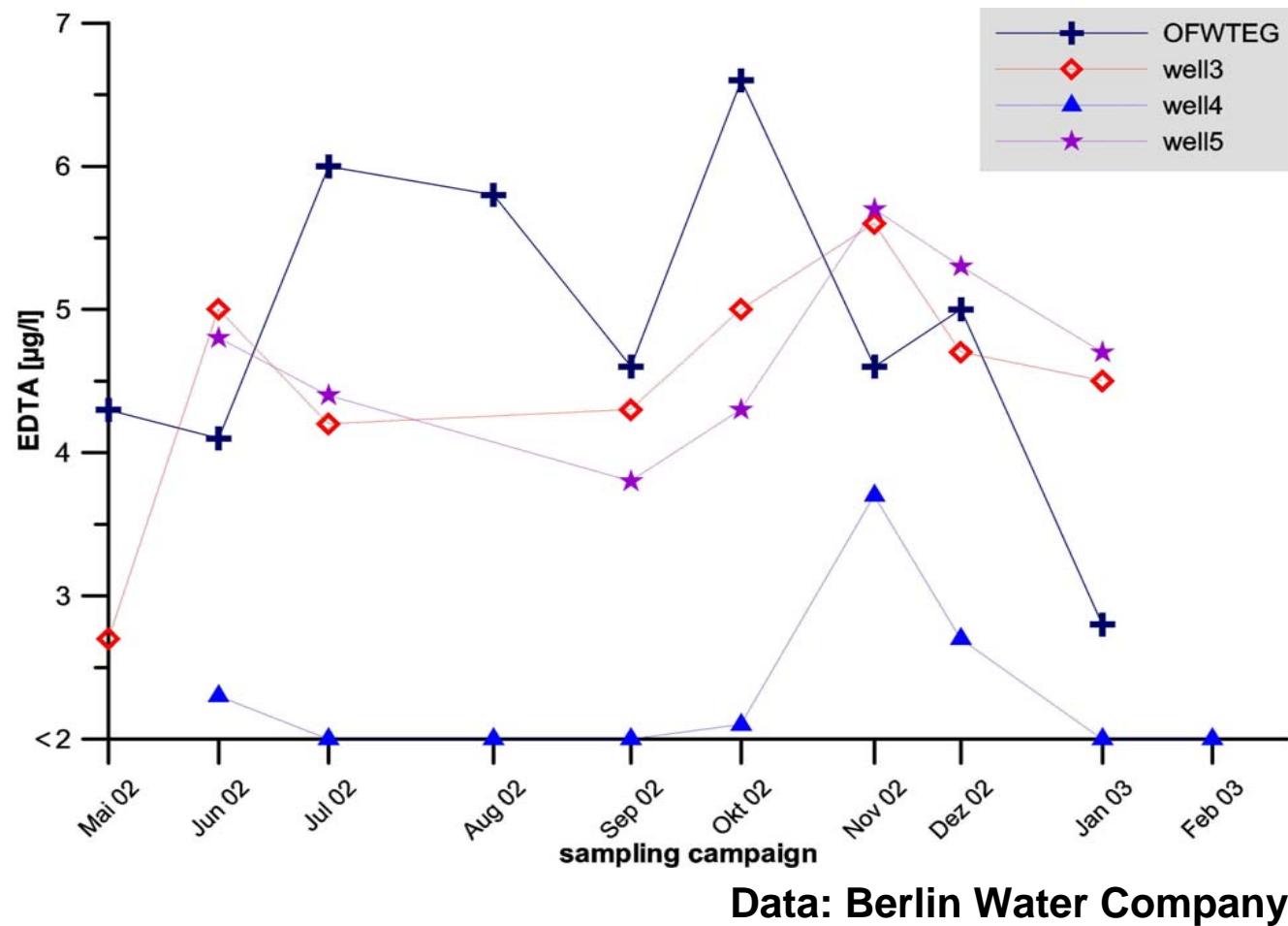
well 3 (new transect)
has a much higher
proportion of bank-
filtrate!

Data: Alfred-Wegener
Institute Potsdam

Field-site Lake Wannsee

Time-series of EDTA in production wells

Results

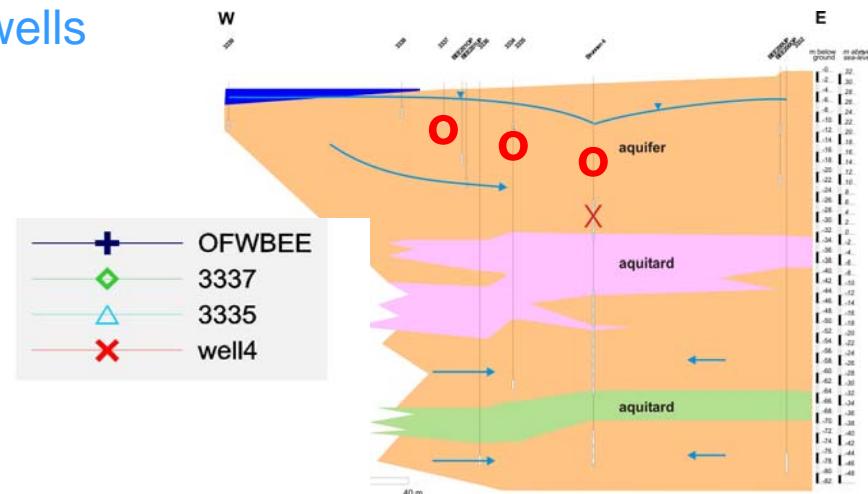
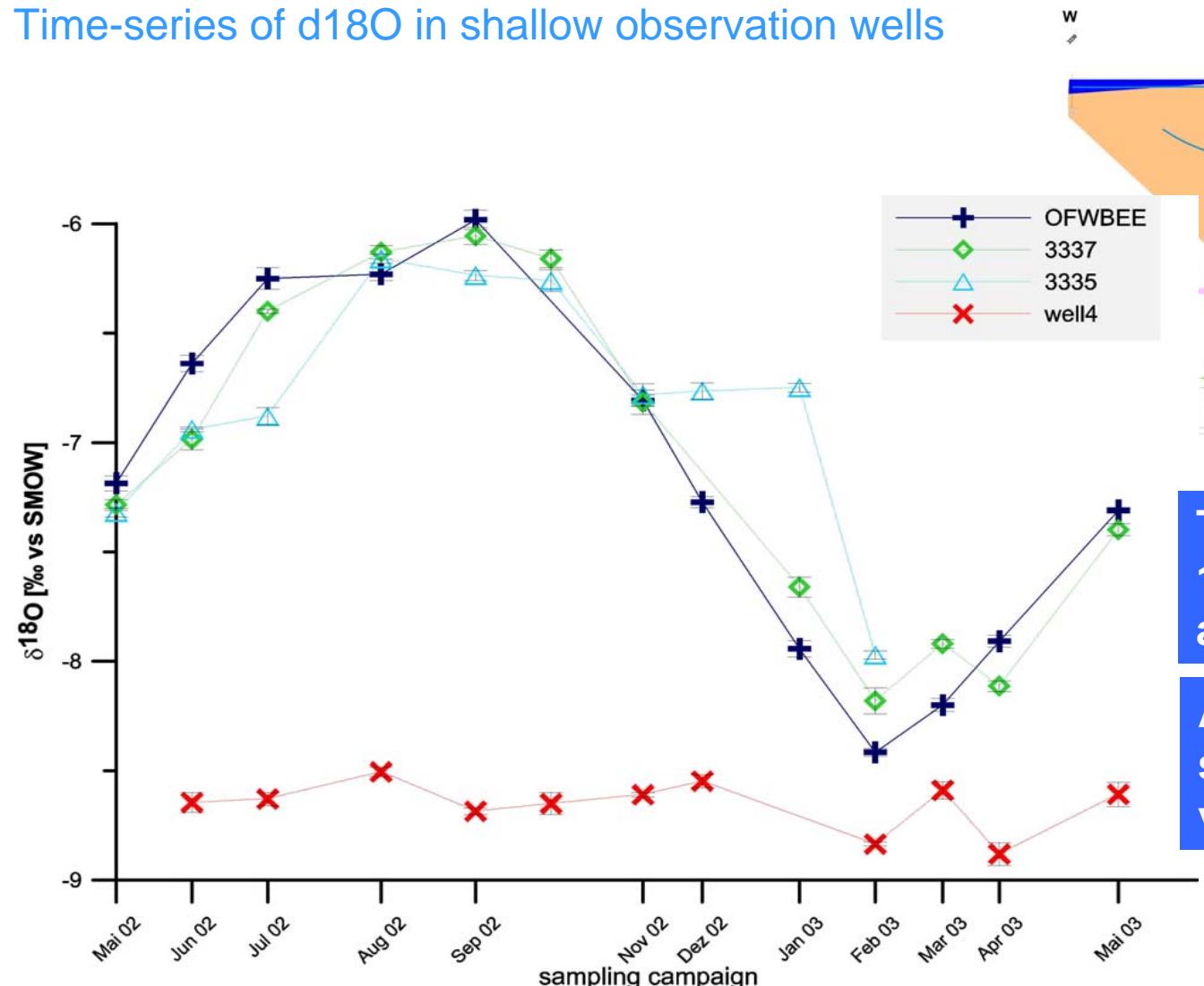


Proportion of bank-filtrate calc. with EDTA:
Well3 = 61-97 %
Well4 = 10-47 %
Well5 = 88-96 %

Transect Lake Wannsee 1

Time-series of $\delta^{18}\text{O}$ in shallow observation wells

Results



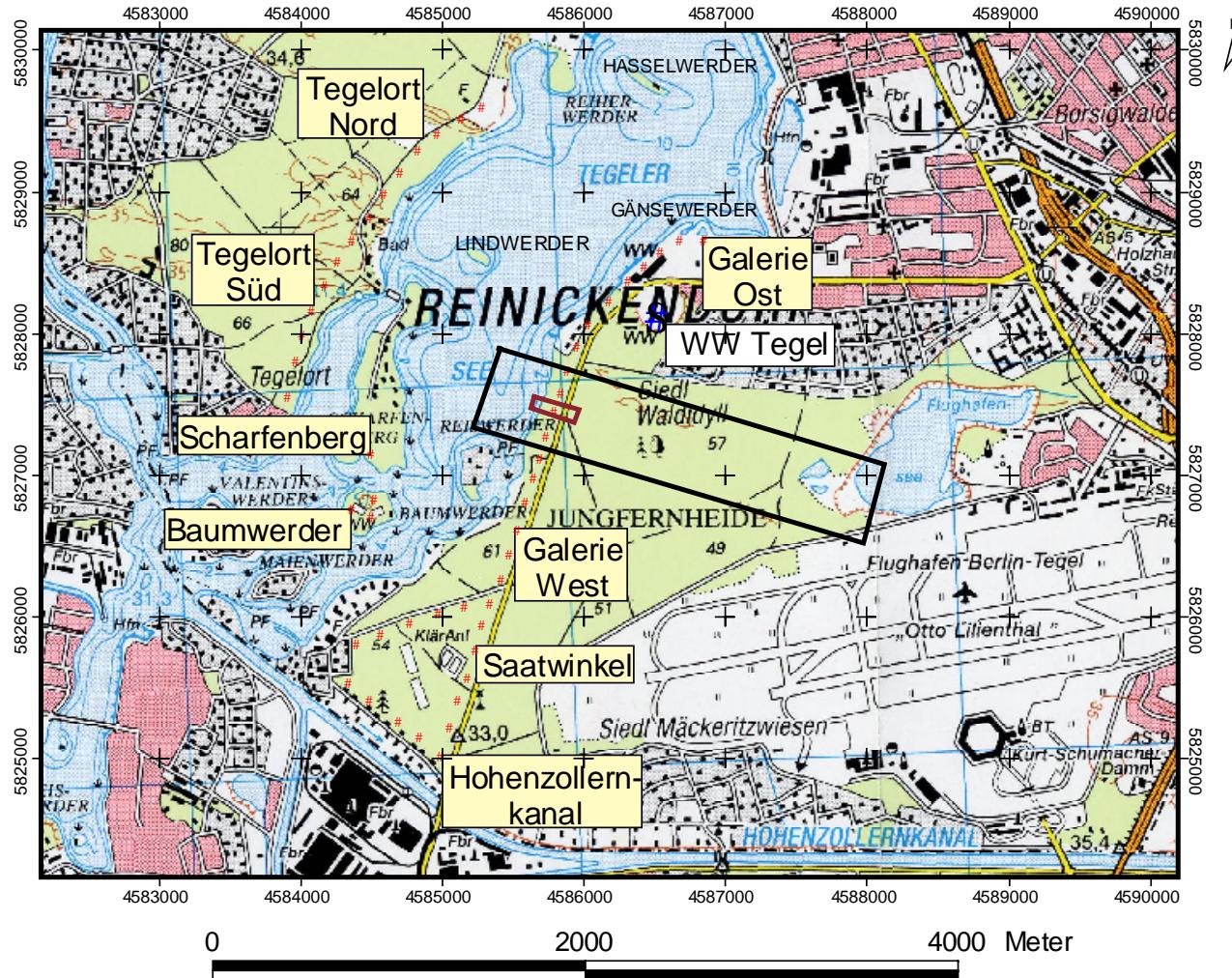
Travel time Lake-well4
1-2 months in shallow
aquifer

All production wells
show no seasonal
variation

Data: Alfred-Wegener Institute Potsdam

Flow model Lake Tegel

Results



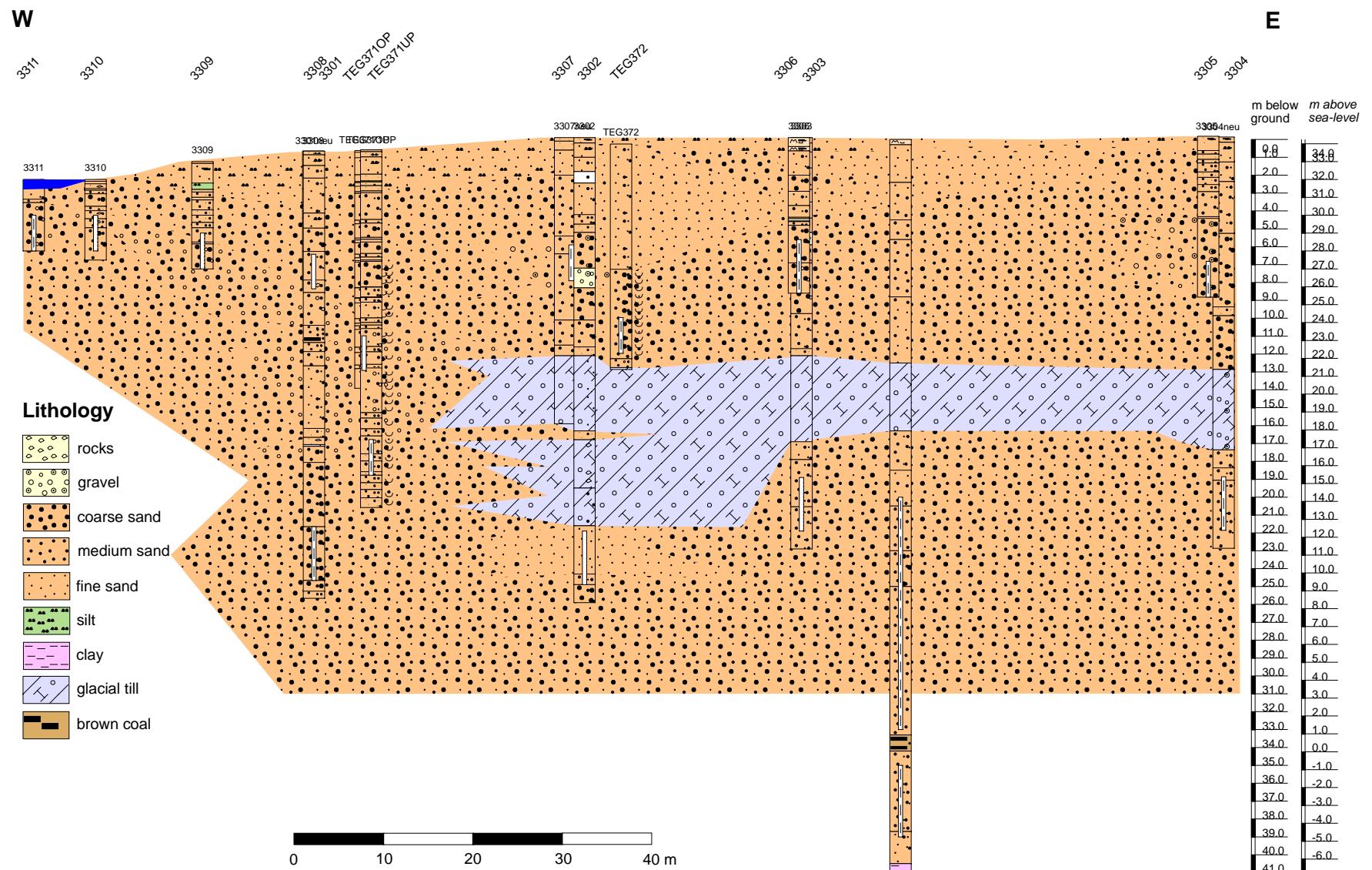
Legend

- # well
- # # # well gallery
- Tegelort Süd name of well gallery
- transect Tegel
- model region

Kartengrund: TK 50 Blatt L3544
Berlin-Spandau, 1998
Koordinaten: Gauß-Krüger
Potsdam-Datum (Zentralpunkt Rauenberg)
Besselellipsoid
Erstellungsdatum: 12/2002
Bearbeiter: Jeannette Rümmler

Transect Lake Tegel

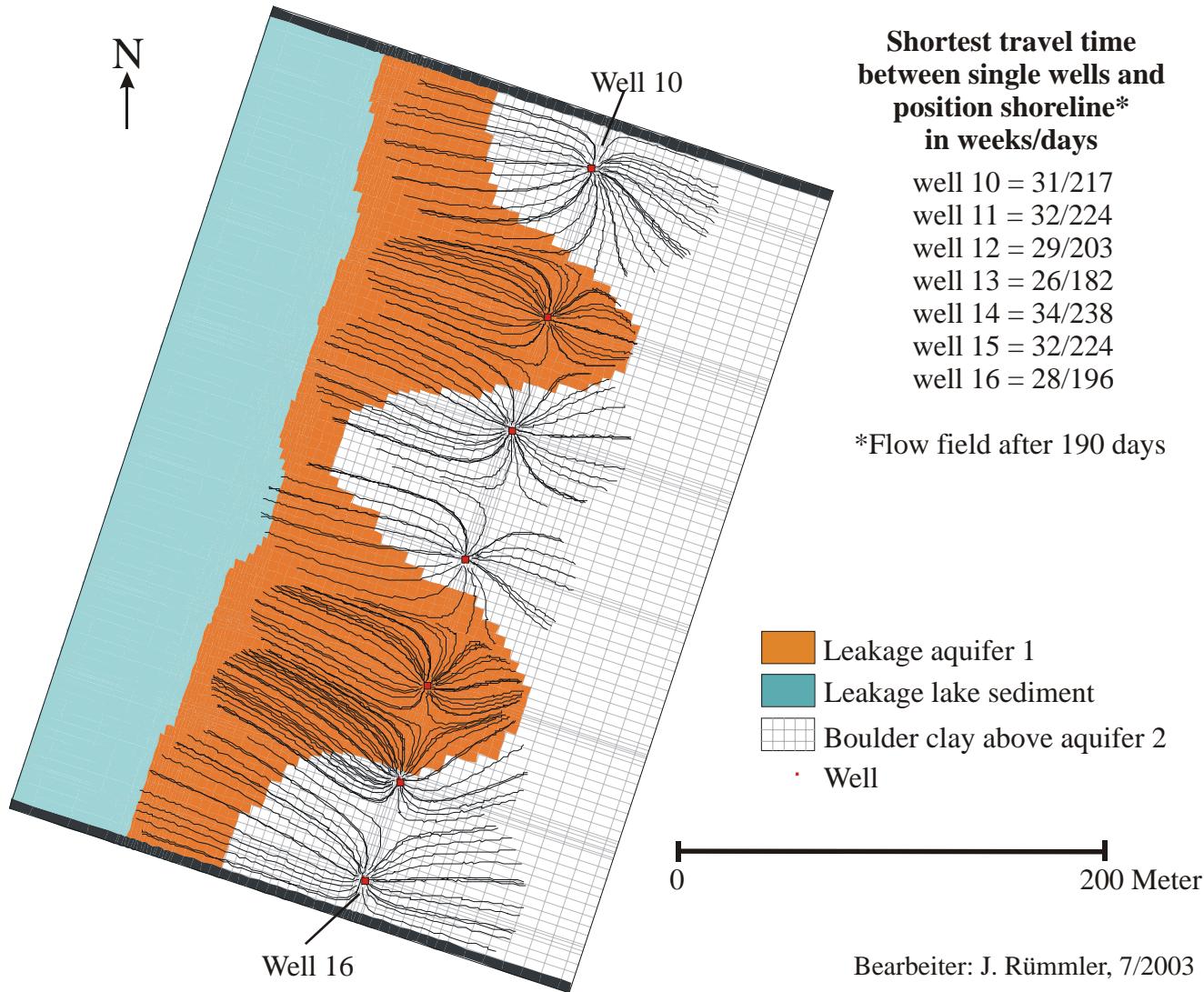
Results



Flow model Lake Tegel

Results

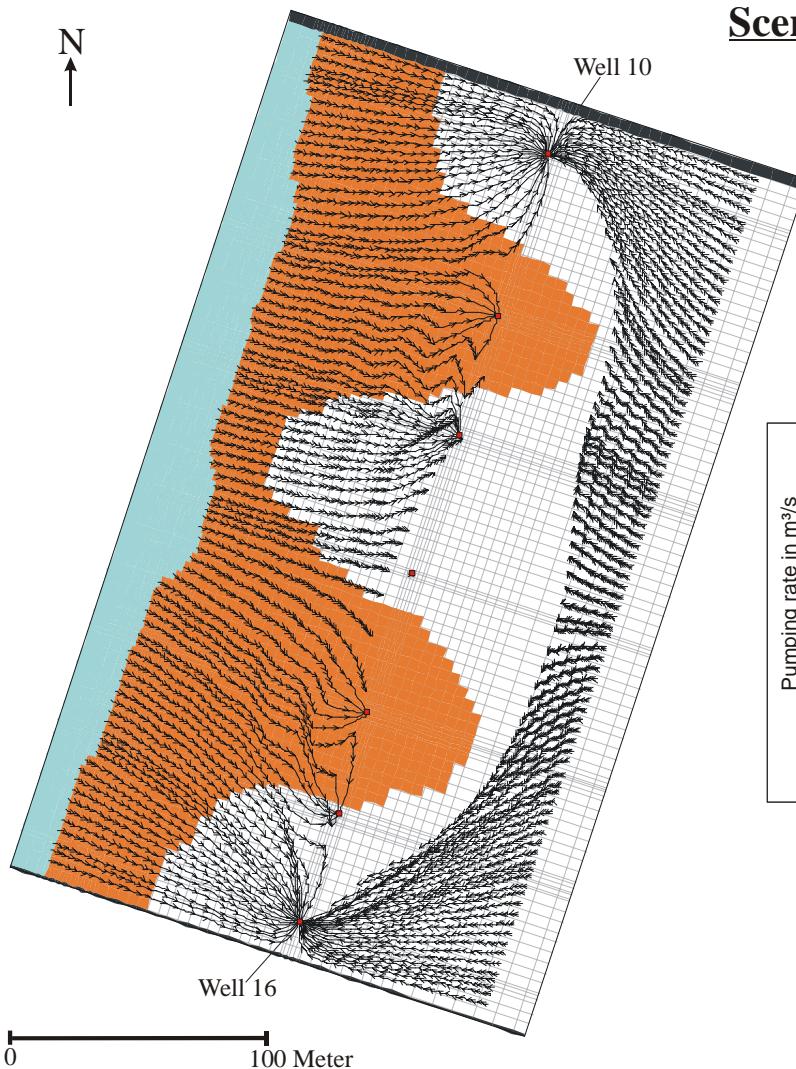
steady state model



Bearbeiter: J. Rümmler, 7/2003

Flow model Lake Tegel

Results

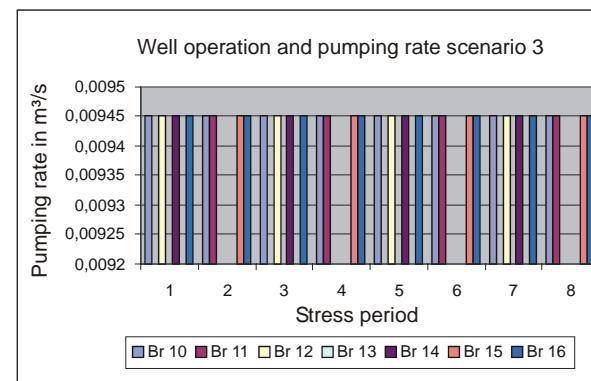


Scenario 3

Shortest travel time
between single wells and
position shoreline in weeks

Br 10 = 23
Br 11 = 29/30
Br 12 = 29
Br 13 = -
Br 14 = 30/31
Br 15 = 32
Br 16 = 22/23

Pumping regime is very
complicated –
**Flow models help to
understand the influence
of different pumping
scenarios on
groundwater flow paths!**

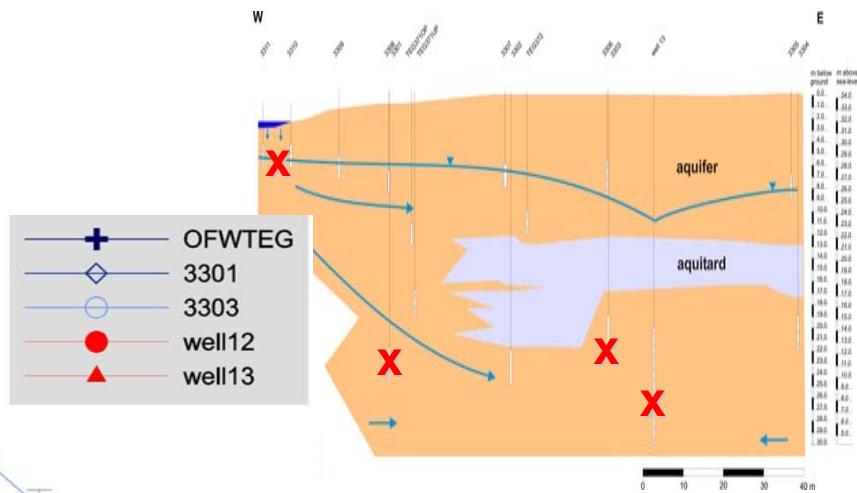
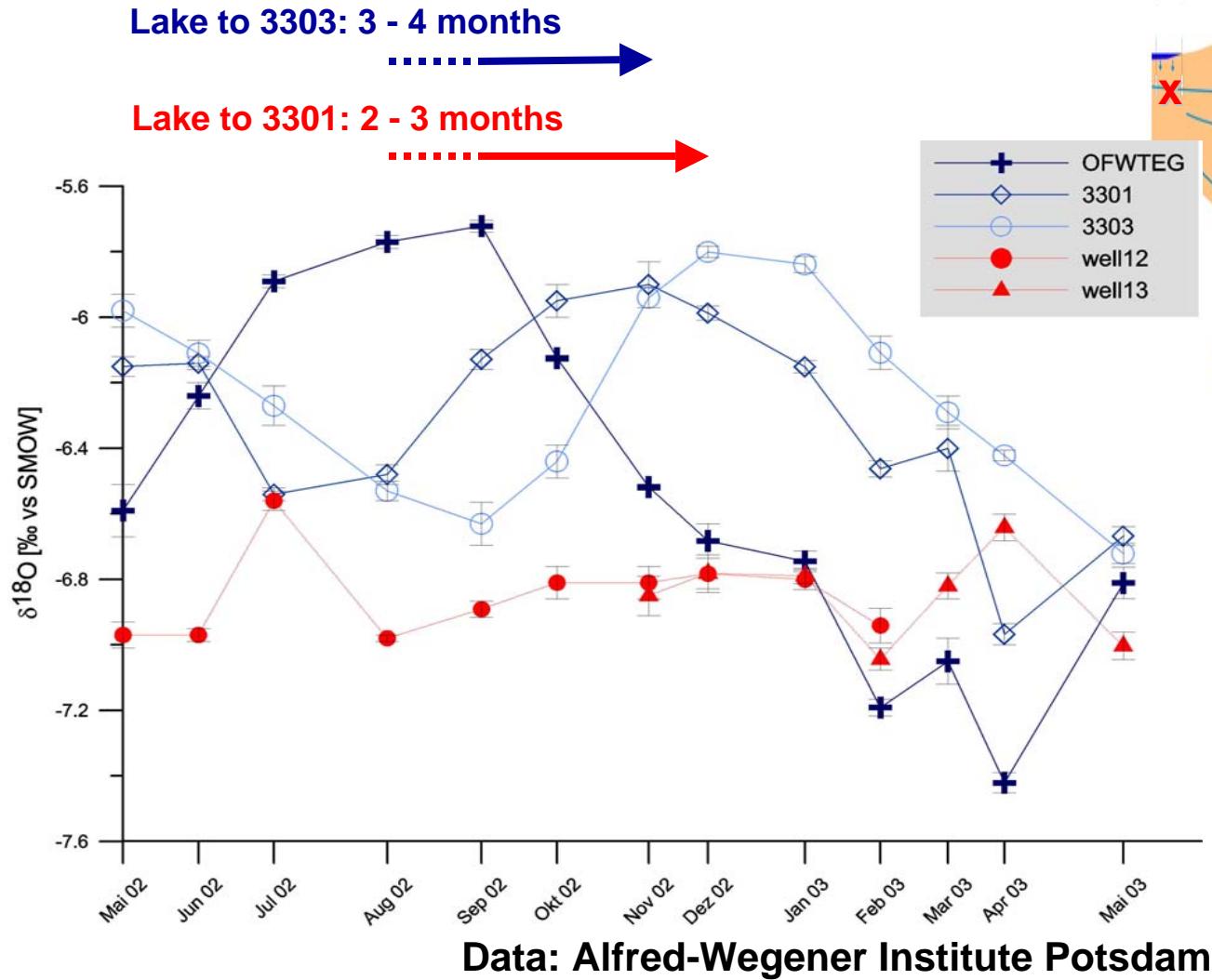


Legend:
■ Leakage aquifer 1
■ Leakage lake sediment
■ Boulder clay above aquifer 2
• Well
Interval <----= 1 Week

Bearbeiter: J. Rümmler, 7/2003

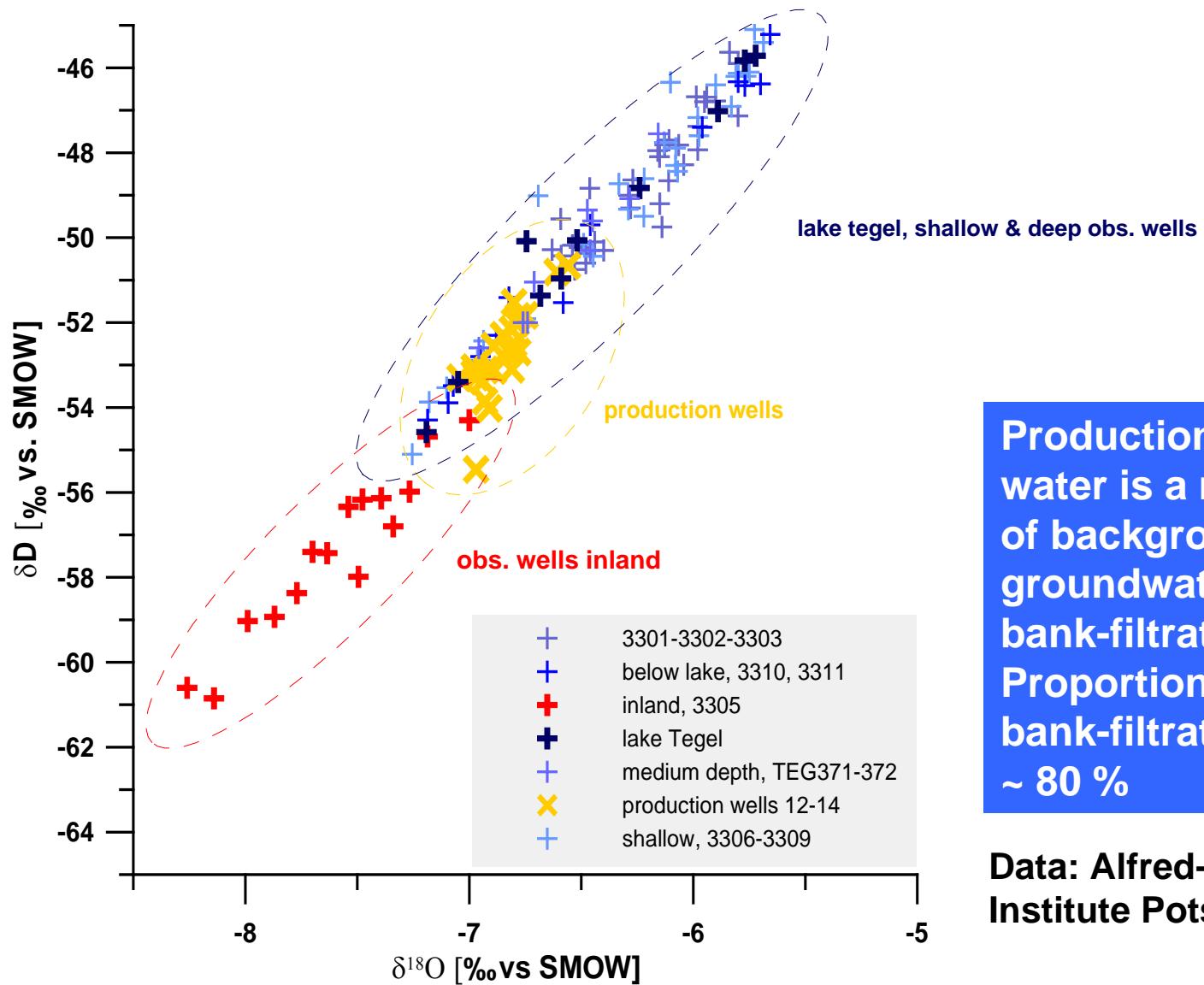
Lake Tegel, age dating and hydrochemistry

Results



Production well water shows no seasonal variation
Travel time Lake-well 13:
6-9 months (Fritz 2002)

Transect Lake Tegel, dD versus d¹⁸O

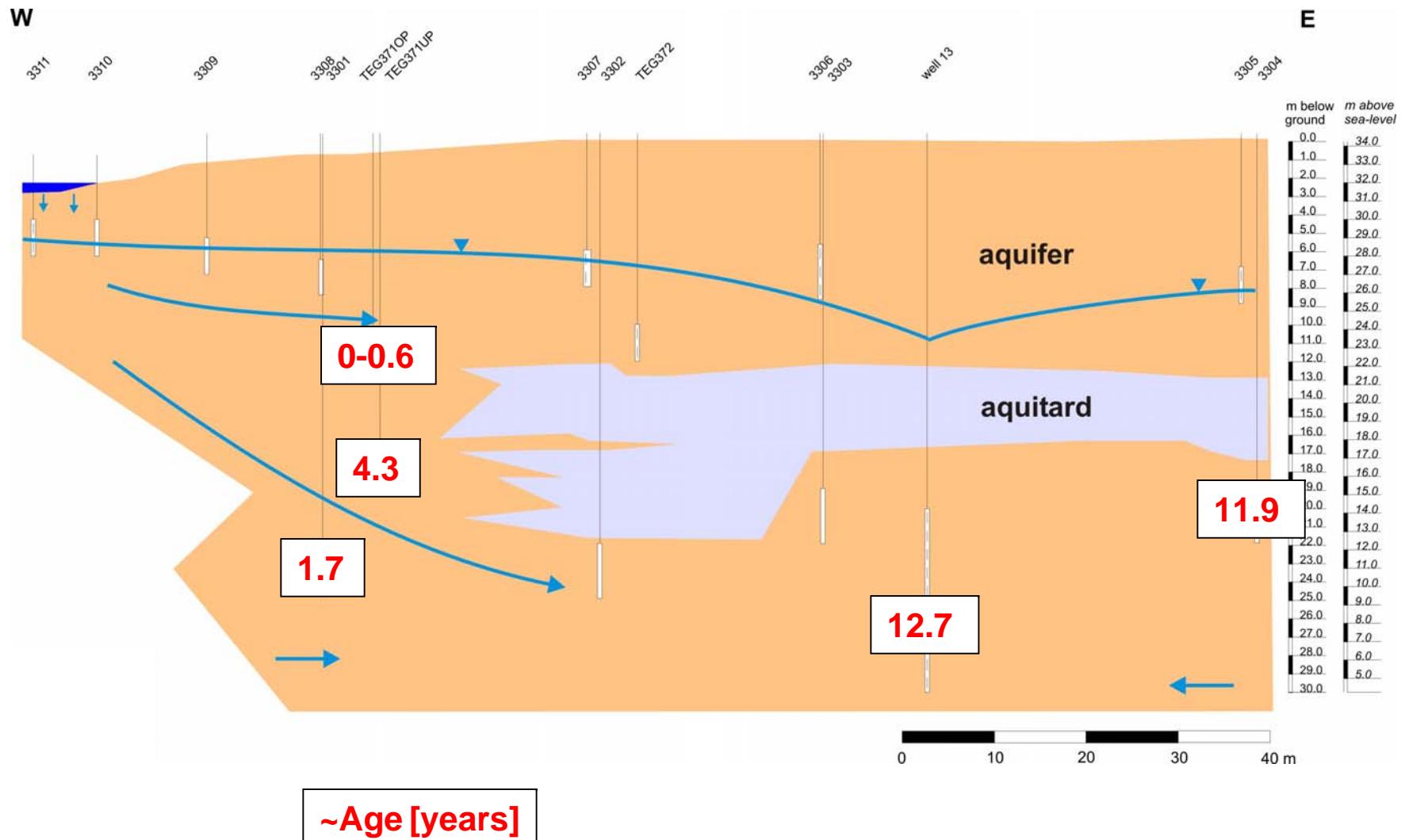


**Production well water is a mixture of background groundwater and bank-filtrate
Proportion of bank-filtrate:
~ 80 %**

Data: Alfred-Wegener Institute Potsdam

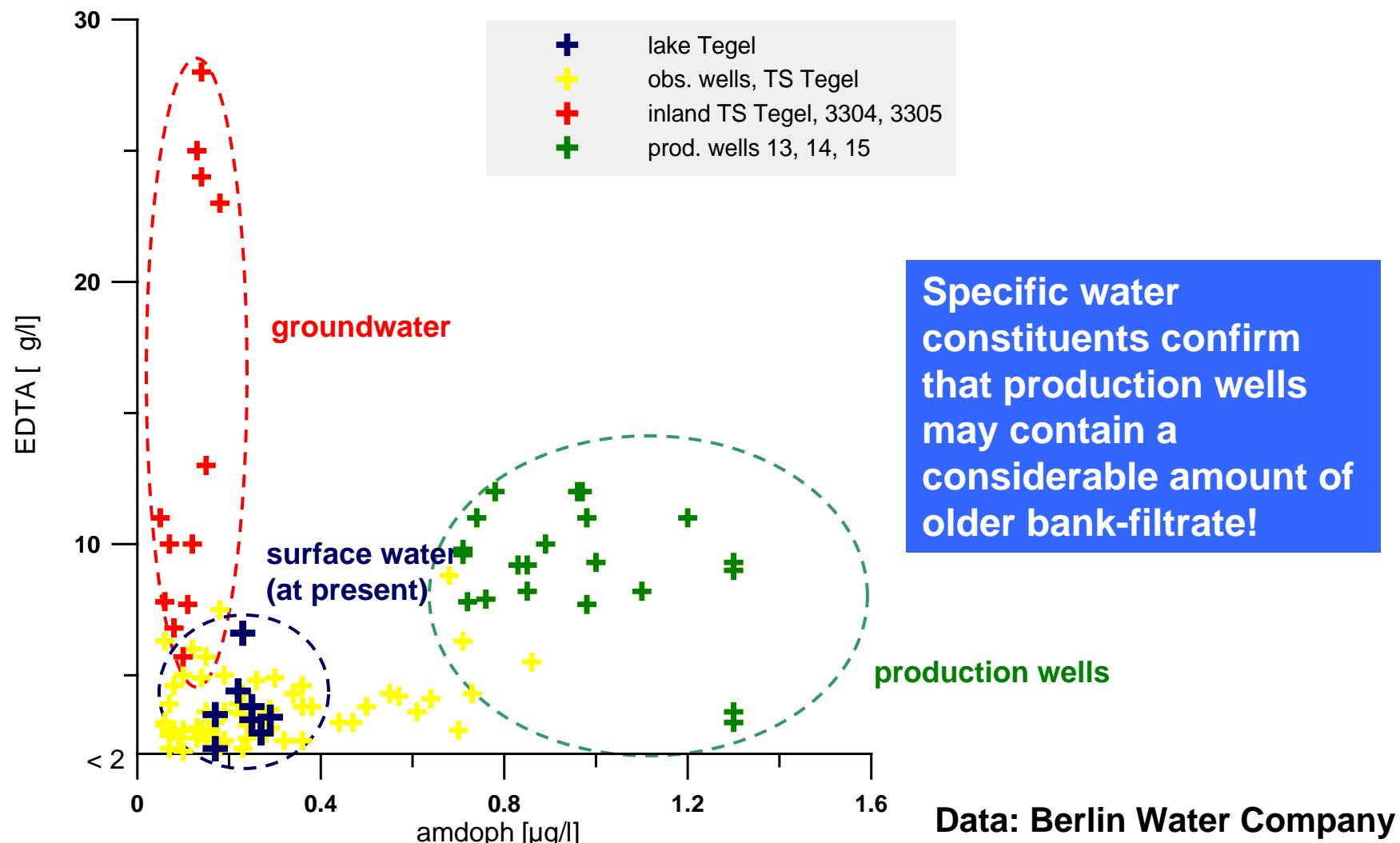
Lake Tegel, age dating

Results



Lake Tegel, age dating

Results

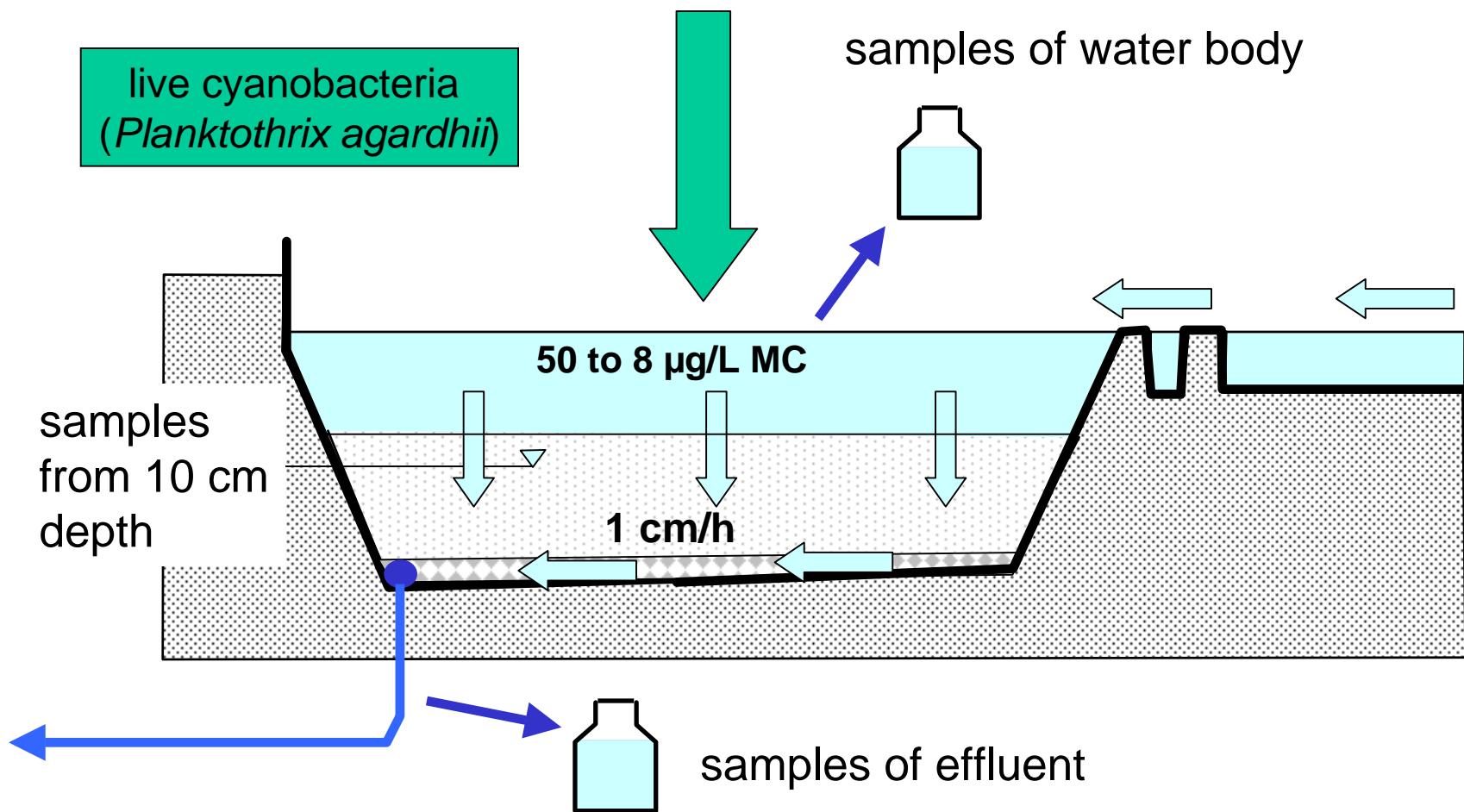


Summary & Conclusions

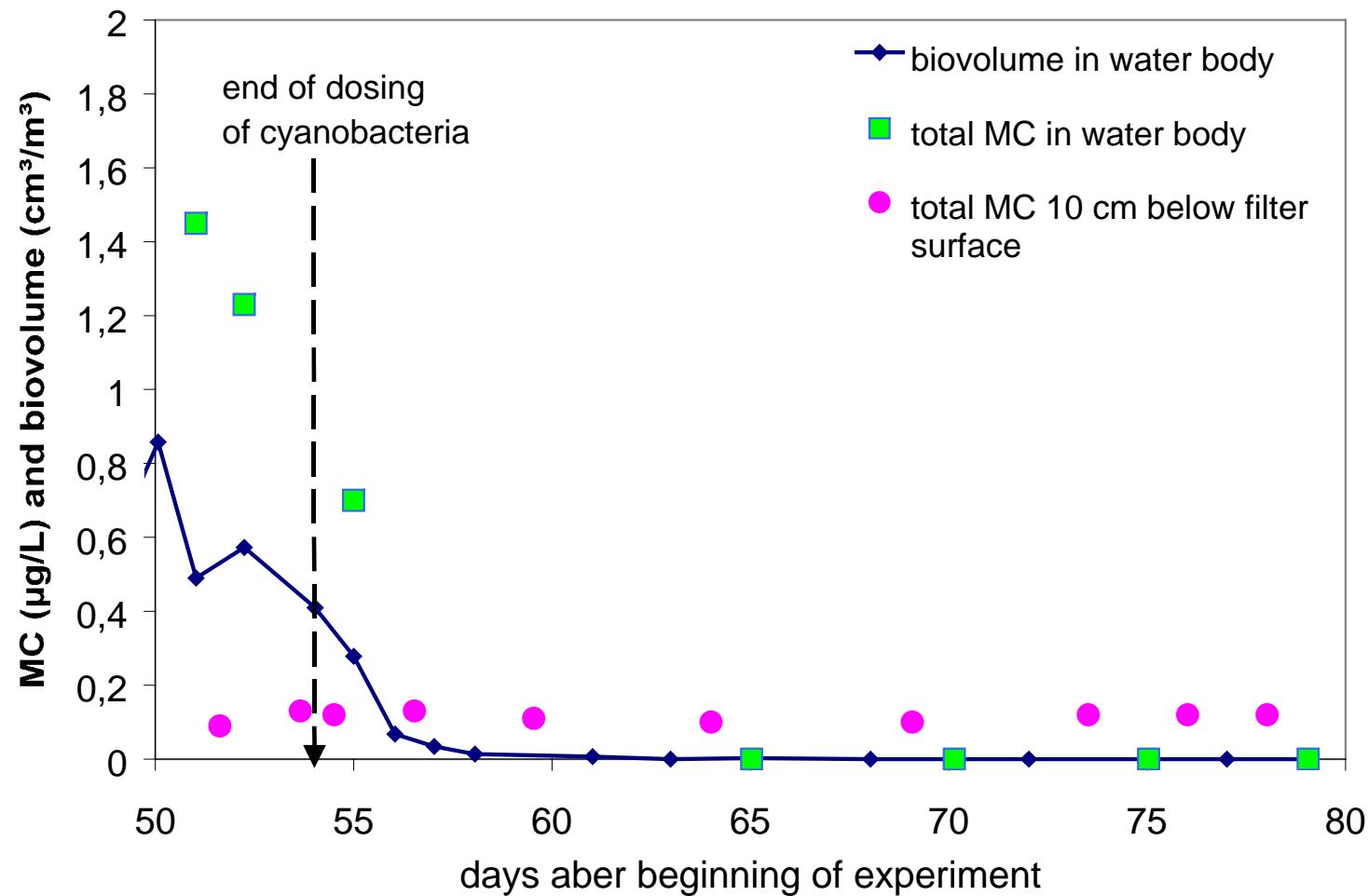
- Combining a number of tracer may help to understand the hydrogeology and hydraulics at a very complex bank-filtration system in Berlin.
- With the help of T/He, ages of groundwater from different aquifers can be estimated.
- Combining discharge measurements with the concentrations of wastewater indicators, proportions of wastewater in the surface water can be calculated. (Wannsee: \varnothing 8.5 % in winter, 20.1 % in summer; Lake Tegel \varnothing 12 % near respective transects).
- With tracers showing strong seasonal variations in the surface water, travel times can be estimated (Lake to wells: Wannsee: 1-2 months, Tegel: 5-8 months).
- Relatively “young” water constituents like EDTA are only present in the bank-filtrate and can be used to calculate proportions of bank-filtrate in the wells at Lake Wannsee. Large differences exist in the different wells (~ 10 % BF in well 4, ~ 90 % BF in well 5).
- At Lake Tegel, proportions of bank-filtrate in the wells are generally high (~ 80 % in average).
- Age dating, lack of seasonal variations in the wells as well as substances formerly present in the surface water in higher concentrations (e.g. amdoph) indicate that a proportion of the bank-filtrate is much older than predicated from observation wells.



Slow Sand Filter Experiments



Cellbound / Extracellular Cyanotoxins (Microcystins)



→ Cells can act as long-term source for microcystins